Latewood density of pine trees for a 1000-year temperature reconstruction in Albania

MedCLIVAR Exchange Grant

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1. Purpose of the visit

Motivation

Recent global warming and its impact on the hydrological cycle and subsequent ecological implications strengthens the need to quantify the degree of past natural climate variability. This demand becomes even more critical particularly for drought sensitive, though densely populated regions with intense agricultural background, such as most of the Mediterranean basin. This holds even more when considering general circulation models, which predict a further decrease in precipitation in the near future (**Hertig and Jacobeit 2008**) and an increase in the frequency of weather extremes (**Meehl and Tebaldi 2004**). Climatic conditions in the Mediterranean exhibit a high degree of spatial variability due to the complex interaction of synoptic circulation patterns (**Dunkeloh and Jacobeit 2003; Xoplaki et al. 2003; 2004**) and local peculiarities due to specific thermal and orographic situations (**Fernandez et al. 2003**). Thus a broad temporal and spatial coverage of palaeoclimatic indicators is required to reconstruct annual to century-scale climate variability. In this context, besides historical documentary data, tree-rings are seen to be the most important high resolution climate proxy for large areas around the Mediterranean (**Luterbacher et al. 2006; Piervitali and Colacino 2001**). Long-term tree-ring based climate reconstructions have been developed for the Iberian Peninsula (**e.g., Buentgen et al. 2008**), Morocco (**e.g., Esper et al. 2007**), north-eastern Italy (**e.g., Serre-Bachet 1994**), and the south-eastern Mediterranean (**e.g., Akkemik and Aras 2005, Touchan et al. 2005**).
Specifically on the Balkan Peninsula, a key region in the climatic transition zone between the western and eastern Mediterranean and also between the Mediterranean and Central European synoptics (**Griffiths et al. 2004; Xoplaki et al. 2003, 2004; Nicault et al. 2008; Qiriazi and Sala 2000**), reliable proxies are very scarce (**Vakarelov et al. 2001; Panayotov et al. 2009, 2010; Büntgen et al. 2006; Popa & Kern 2009**). Albania appears as a pure white spot in terms of existing tree-ring studies but at the same time provides large areas of *Pinus heldreichii* CHRIST trees, an endemic, long-living high-elevation species on the Balkan and southern Italy (**Griffiths et al. 2004; Panayotov and Yurukov 2007; Popa and Kern 2009, Vakarelov et al. 2001; Panayotov et al. 2009, 2010**).

Aim

The general aim of the project is to develop a >1000-year, highly replicated maximum latewood density (MXD) chronology from living and relict material in Albania. Initial tests with a small sample subset indicate a robust summer temperature signal. Comparisons with other recently established, although shorter Mediterranean MXD records (e.g. Bulgaria, **Trouet et al. (submitted)**, but also from the Pyrenees, **Buentgen**

et al. 2008) should enable to put regional and larger-scale natural and man-made climate variability of the 21st century in a long-term Mediterranean context.

In particular, my personal goal of the visit was to contribute to this general one:

1) preparing a manuscript about the characteristics of the tree-ring width chronology to be submitted to a scientific journal
2) learning the procedure for density measurements for development a maximum latewood density chronology for Albania

2. Work description at the WSL

The internship was completed at the Dendro-Sciences unit of the Swiss Federal Research Institute for Forest, Snow, and Landscape, WSL, from June 1st to October 15th 2010, for a total of 18 weeks. During this time I was able to work on the preparation of the manuscripts and to prepare a sufficient number of density measurements to exploring the climate signal

2.1. Scientific paper

For the preparation of the manuscript I had to collect all tree-ring width data and analysis from the diploma work to prepare adequate figures and tables. Before preparing an initial draft with results of growth-climate relationships reanalyses of the TRW data set were carried out. The objective of the manuscript was to 1) inform about the existence of a new and millennium-long tree-ring width chronology from Albania and 2) to describe its characteristics in terms of strength of the common and climatic signal. Due to the scarcity of available data sets for the Balkan Peninsula and general Eastern Mediterranean region it is important to present a unique TRW chronology of *Pinus heldreichii* spanning the period 968-2008 (after truncation of 5 series). Unfortunately, the climate signal observed in the ring width is not strong and clear enough for climate reconstruction. Correlations between tree-ring width data (TRW) and various instrumental data generally remain rather weak and point to a mixed climate signal (**Seim et al. 2010**). Necessarily, due to similar results found in Italy (**Todaro et al. 2007**), Greece (**Brandes 2007**) and Bulgaria (**Panayotov et al. 2009, 2010)** our investigations lead to the development of a high-elevation pine tree-ring network to investigate this specific climate pattern across the Mediterranean region.
Generally, the complex climate signals contained in tree-ring width needs to be better understood and therefore the measurement of additional proxy, as the wood density, might help to extract climatic valuable information from this unique chronology.

2.2. Maximum latewood density (MXD)

The additional samples were carefully selected based on the results of the cross-dating and development of the TRW-chronology (**Tab. 1**). The preparation for X-ray densitometry of these samples was carried out in the following steps.

The first stage was to remove the resin out of the samples and therefore the disks were individual sawed and split into smaller pieces to fit them into cellulose tube of 2,5 in diameter and 10 length for the Soxhlet extractor.

Figure 1: Several fragments of disc No. ABS2a that are used for the MXD measurements in their correct order.

The cores mostly fit in these tubes already. Altogether, the samples had to stay for two to three days in 96% alcohol vapour to remove the resin completely.

After breaking these disk fragments as well as the additional 18 cores into 1 to max. 3 cm long pieces they were mounted on wooden strips, glued and labelled. The orientation of the fragments is with the radial surface uppermost.

Finally, a 1.5-mm-tick lath of each fragment were cut out with a small twin-bladed circular saw (**Fig. 2**) and puzzled on a film holder back in their right order and labelled again (**Fig. 3**).

Figure 2: Sawed samples on the wooden strips.

Figure 3: Ordered and labelled 1.5 mm laths archived after the film development.

A double-coated medical X-ray film was irradiated with X-rays for 70 min and in 250 cm height. Film development followed standardized techniques. Density measurements are based on grey values and each film is adjusted using a calibration wedge and brightness variations were conveyed into g/cm³.

Table 1: Number of samples prepared (left), measured (middle) and cross-dated (right) for developing a MXD-chronology for Albania.

Code	Years	Date begin	Date end	Code	Years	Date begin	Date end	Code	Years	Date begin	Date end
Samples prepared				**Samples measured**				**Test data set**			
AT				**AT**				**AT**			
AT4S1a	594	1303	1896	AT315a2	362	1646	2007	AT302a	240	1768	2007
AT4S1b	554	1327	1880	AT315ad	328	1679	2006	AT304b2	205	1803	2007
AT401d	638	1369	2006	AT308b	127	1881	2007	AT301b2	195	1808	2002
AT2001	489	1417	1905	AT307a	113	1895	2007	AT304b1	187	1821	2007
AT1d01b	350	1490	1839					AT306a	100	1908	2007
AT1d01a	190	1660	1849								
AL				**AL**				**AL**			
AB1007	815	1184	1998	AL04100	186	1792	1977	ABS6b	496	1498	1993
ABS1a	905	1022	1926	AL04011a	234	1775	2008	ABS6a	497	1493	1989
ABS1b	928	1003	1930	AL04049a	320	1689	2008	ABS2a	662	1341	2002
ABS2a	662	1341	2002	AL04058d	437	1572	2008	ABS5a	1017	968	1984
ABS5a	1017	968	1984	AL04095	445	1558	2002	ABS5b	988	967	1954
ABS5b	988	967	1954	AL04016a	552	1457	2008				
AL03SW2	653	1166	1818	AL03SW5	560	1372	1931				
AL04015b	455	1313	1767	AL04041a	645	1356	2000				
AL04020d	502	1265	1766	AL04091	692	1309	2000				
AL04032a	520	1487	2006	AL04089	660	1286	1945				
AL04036	636	687	1322	AL03SW1	706	1243	1948				
AL04038a	639	1361	1999								
AL04039d	611	1210	1820								
AL04054b	574	1418	1991								
AL04081	532	1349	1880								
AL04082	700	824	1523								
AL04092	548	1183	1730								
AL04093	532	1237	1768								
AL04094	515	1268	1782								
AL04096	518	1323	1840								
AL04098	559	1209	1767								
AL04120	750	1252	2001								
AP											
AP01020a	505	1504	2008								
AP01024a	563	1445	2007								
AP01034a	584	1425	2008								
AP01035a	566	1443	2008								
AP01038a	604	1405	2008								
AP01040b	591	1418	2008								
AP01061a	520	1489	2008								
AP01092c	498	1511	2008								

In total, 14 disks and 22 cores were used. After the aforementioned preparation ten films including the 36 samples were finally developed and are complete for measuring.
Moreover, 15 samples were prepared in 2009/2010 and the density could be measured with a WALESCH 2003 X-ray densitometer.
For reasons of the highly time-consuming sample preparation for the maximum latewood measurements the MXD chronology is going to be develop when all 36 samples will be measured which is planned in 2011. In this manner it has to be considered that the measurement and cross-dating of MXD series will demand one to two additional months because of the rather difficult material and exceptionally long segment length.

3 Results

3.2 Projected publications/ Manuscripts

We work on manuscripts containing the obtained results.

Tentative references for these papers are:

Seim A, Treydte K, Fonti P, Haska H, Herzig F, Tegel W, Trouet V Büntgen U (in prep): "A new millennium-long tree-ring chronology from Albania" for submission to *Climate Research*

Seim A, Treydte K, Fonti P, Tegel W, Panayotov M, Trouet V, Büntgen U (in prep.): "Climate sensitivity of Mediterranean pine growth" for submission to *Ecography*

3.2 MXD

Since some samples still remaining unmeasured we did not start analysing all the density data yet. For explorative reasons we however analysed data issuing from 7 series. These results are presented here. **Figure 4** shows the raw measurements of the each series as well as the developed mean curve used for the growth-climate analyses.

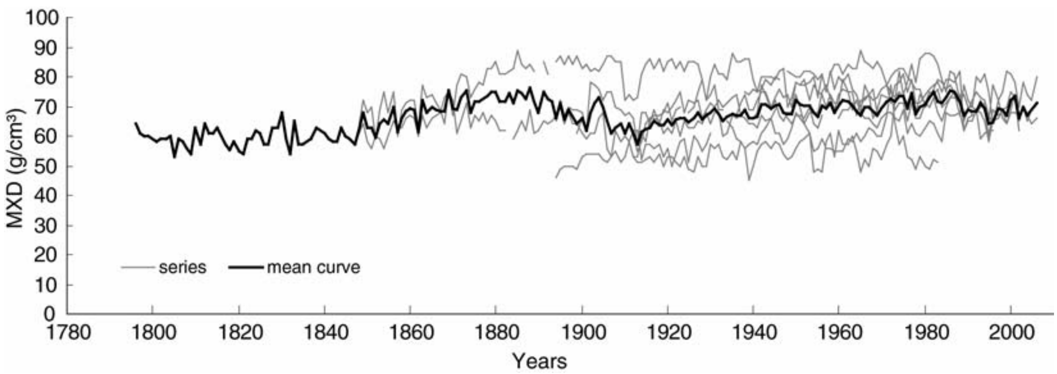

Figure 4: Raw maximum latewood density series (grey) and the mean curve (black) of the test data set.

The raw data were detrended using a cubic smoothing spline of 100-year frequency-response cut-off by 50% considering the shortness of the series.

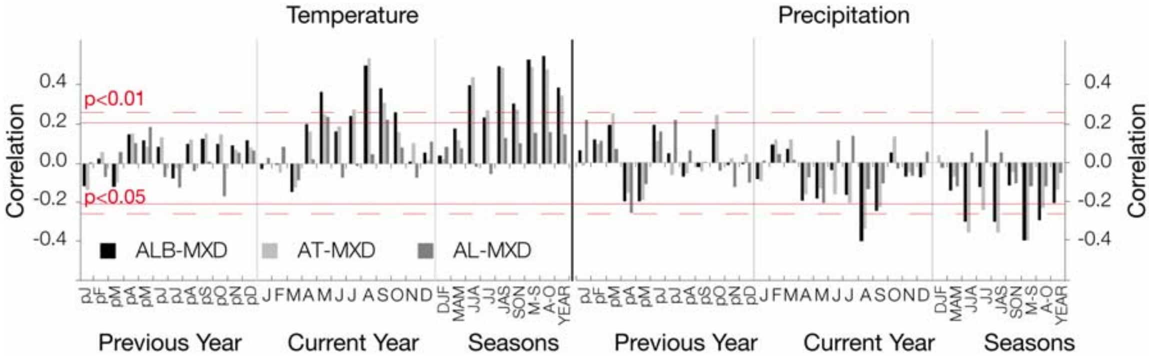

Figure 5: MXD chronologies (composite and site chronologies) correlated with gridded temperature and precipitation data (CRUTS3) for the 1901-2001 periods. Red continuous and dashed lines indicate the 95% and 99% significance level.

Growth-climate relationships between tree-ring chronologies and climate conditions where performed using the high-resolution grid points (0.5°x0.5°) and monthly resolved climate indices of the CRUTS3 dataset (**Mitchell and Jones 2005, van der Schrier et al. 2006**). Climatological data were available for the period AD 1901-2006.

High positive correlation with temperature is observed not only for various summer months. Considering a whole seasonal window from April to October the correlation is 0.55 exceeding the 99% significance level (**Fig. 5**).

Moreover, while tree-ring width correlation with climate data is unstable over the full calibration period, the MXD chronology shows a rather consistent climatic signal over 100 years (**Fig. 6**).

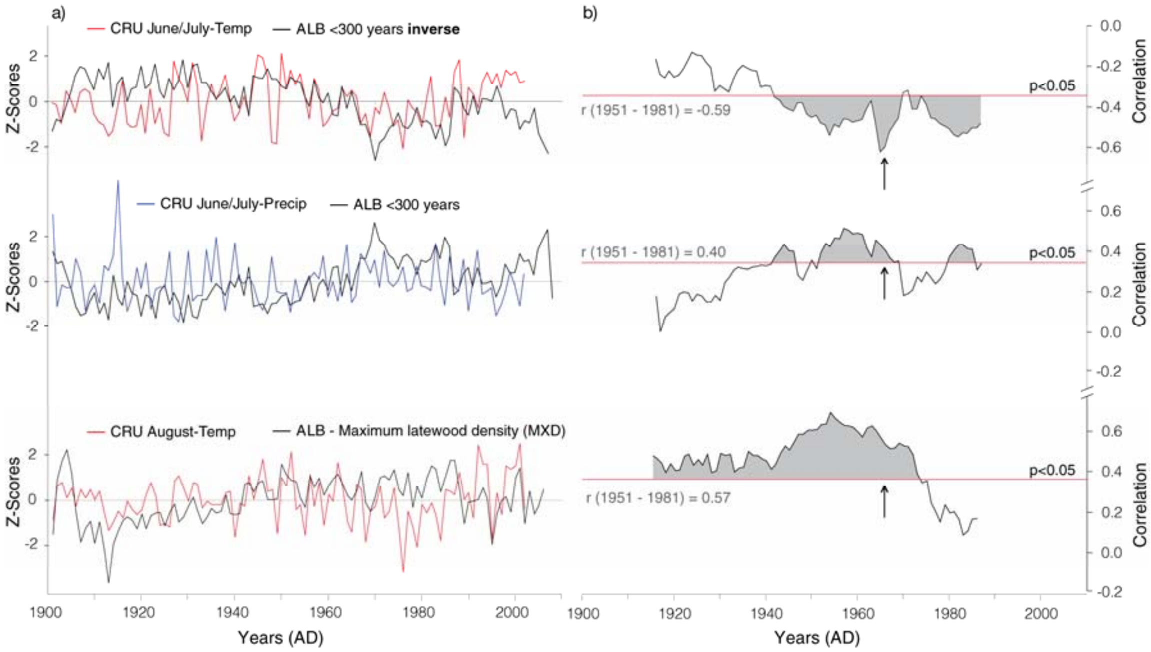

Figure 6: a) RCS-detrended chronologies and gridded instrumental data (CRUTS3) for June-July. **b)** 31-year running correlations of TRW (separated by age class) and MXD with CRU-data close to Tirana (T+P: 1901-2002). Arrows indicate the correlation obtained with instrumental data of Tirana. Grey are correlations above $p<0.05$.

Considering not only time stability a spatial field correlation was carried out. We observed that correlations with temperature have spatial relevance and consistent high positive and significant relationships. This signal represents a broader region over the Balkan and southern Italy (**Fig.7**).

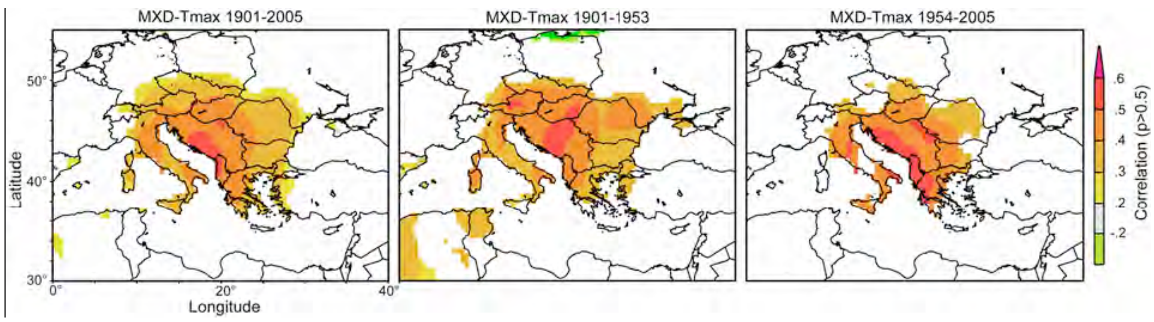

Figure 7: Spatial field correlations of a low-replicated 100-year spline detrended MXD-chronology to a) averaged May-September temperatures (CRUTS3) for the full period of investigation and two independent sub-periods (b and c).

4. Conclusion

I set the base to develop a well-replicated MXD chronology for Albania, which provides the basis for a reconstruction of summer temperatures on the Balkan over the full past millennium, a region still lacking this kind of information. These results will markedly

increase our knowledge about the potential of MXD measurements from high elevation sites for temperature reconstructions in the Mediterranean.
Moreover, with reanalysing TRW data it was possible to produce two additional scientific manuscripts to be submitted to peer-reviewed ISI journals.

5. On-going collaboration with host institution

The collaboration with the host institute WSL in Birmensdorf will continue. In the near future it is planned that I will be for another period at the WSL to finish the measurements and analyses of the maximum latewood density data set. The main focus will be to reconstruct temperatures variability in Albania of which the fundamental work was carried out financed by the ESF MedCLIVAR. The ESF will be considered also in the scientific paper following from this future stay.

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